

CLAIMS

1. An electro-active device comprising a plurality of flex circuits, each having a sheet of film and an electrode on at least one surface of the film, said plurality including at least first and second flex circuits, means forming a recess between said first and second flex circuits, and an electro-active element in said recess bonded to the flex circuits being mechanically and electrically coupled thereto.

2. An electro-active device according to claim 1, constituting a card wherein said element is bonded within the card by a thin layer of curable material.

3. An electro-active device according to claim 2, wherein the curable material is a structural polymer.

4. An electro-active device according to claim 1, wherein the electro-active element is a piezoelectric plate having a thickness under approximately one millimeter.

5. An electro-active device according to claim 4, wherein the piezoelectric plate has a thickness, and first and second cross dimensions, each cross dimension being greater than about ten times the thickness.

6. An electro-active device according to claim 1, wherein the electrodes have an electrode pattern, and said element is bonded to the flex circuit by a planarizing layer of curable material having a pattern complementary to the electrode pattern.

7. An electro-active device according to claim 4, wherein the electro-active element has a surface plane, and electrodes of said first and second flex circuits are patterned for applying an electric field which varies in said plane.

8. An electro-active device according to claim 4, wherein the electro-active element has a surface plane, and electrodes of said first and second flex circuits apply an electric field which varies in a direction normal to said plane.

9. An electro-active device according to claim 1, wherein the electrodes have a comb pattern.

10. An electro-active device according to claim 1, comprising two different electro-active elements in two different respective recesses and oriented to produce torsional actuation.

11. An electro-active device according to claim 1, further comprising a circuit element within the device.

12. An electro-active device according to claim 11, wherein the circuit element includes at least one of a shunt, a filter, an impedance matcher, a storage element, a power source, an amplifier, and a switch.

13. An electro-active device according to claim 11, wherein the circuit element includes a controller.

14. An electro-active device according to claim 1, wherein first and second electro-active elements are connected in different layers of the assembly for moving in different senses.

15. An electro-active device according to claim 1, constituting a device selected from among vanes, airfoils, shakers, steppers, stirrers and sonicators.

16. An electro-active device according to claim 1, having a thickness less than twice a combined thickness of electro-active elements stacked in the device.

17. An electro-active device according to claim 1, wherein the element is selected from among a stack, flexure, shell, plate and bender.

18. An electro-active device according to claim 1, configured as one of a pusher, vane, flap, lever, bender, bellows and combination thereof.

19. An actuator comprising
a flex circuit having conductors, and
a sheet strain element

wherein the flex circuit is assembled with at least some of its conductors in electrical contact with the sheet strain element and is bonded together therewith by a structural polymer into a flat card having an output face with a substantially shear-free mechanical coupling to the flat strain element.

20. A method of perturbing a device, such method comprising the steps of

(i) cementing a card in contact with a region of the device, the card enclosing a sheet of electro-active ceramic material with actuation electrodes, and

(ii) applying an electrical signal to the actuation electrodes to create strain energy in the electro-active ceramic material, whereby the strain energy from the electro-active ceramic material is coupled across a face of the card into said region to perturb the device.

21. A method of forming an actuator, such method comprising the steps of
forming a flex circuit having conductors arranged in a pattern
bonding an electro-active ceramic sheet in contact with at least some of said conductors, and
assembling the flex circuit and the electro-active ceramic sheet with a stiff structural polymer so as to constitute a card such that the sheet has a non-shear coupling to an outer face of the card and is electrically coupled over a region to electrodes of said flex circuit.

22. The method of claim 21, wherein the step of assembling includes assembling circuit elements in said card.

23. A method of forming an electro-active device, such method comprising the step of:
preparing first and second flex circuits with first and second electrodes and a recess therebetween, and
bonding at least one electro-active element in the recess in mechanical and electrical contact with said flex circuits over its surface area to form a unitary electro-active structure.

24. The method of claim 23, further comprising the step of attaching circuit elements on said first and second flex circuits.

25. The method of claim 23, wherein the step of bonding includes bonding plural pairs of electro-active elements.

26. The method of claim 23, wherein said flex circuits are pliable in a region away from said recess.

27. The method of claim 23, wherein the step of preparing includes preparing at least three flex circuits.

28. The method of claim 23, further comprising the step of bonding a surface of one of said flex circuits to an object whereby the device mechanically acts on said object through the flex circuit when signals are applied to the electrode.

29. The method of claim 23, wherein the step of bonding is performed with a patterned layer of bonding material co-planar with at least some of said electrodes.

30. The method of claim 23, wherein the step of bonding hardens the flex circuits and bonded electro-active element into a card.

31. The method of claim 23, wherein the device constitutes a simple mechanical device selected from among pushers, vanes, flaps, levers, benders, bellows and combinations thereof.